



Marsbound! Mission to the Red Planet

High School NGSS, Common Core, and 21st Century Skills Alignment Document



WHAT STUDENTS DO: Design a Mission to Mars.

Curious about how engineers design a Mars mission? In this fun, interactive card game, students experience the fundamentals of the engineering design process, with a hands-on, critical-thinking, authentic approach. Using collaboration and problem-solving skills, they develop a mission that meets constraints (budget, mass, power) and criteria (significant science return). This activity can introduce many activities in technology education, including robotics and rocketry. In this collection, it deepens skills from Lesson 6 and builds them for Lesson 12.

NGSS CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES
<p>HOW DO ENGINEERS SOLVE PROBLEMS? <i>NGSS Core Question: ETS1: Engineering Design</i></p> <p>What Is a Design for? What are the criteria and constraints of a successful solution? <i>NGSS ETS1.A: Defining & Delimiting an Engineering Problem</i></p> <p>What Is the Process for Developing Potential Design Solutions? <i>NGSS ETS1.B: Developing Possible Solutions</i></p> <p>How can the various proposed design solutions be compared and improved? <i>NGSS ETS1.C: Optimizing the Design Solution</i></p>	<p><i>Students will be able</i></p> <p>IO1: to model a technological design solution (mission) within the constraints and limitations of the problem</p>



1.0 About This Activity

Mars lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (see *Section 4* and *Teacher Guide* at the end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures. Construction of rubrics also draws upon Lanz's (2004) guidance, designed to measure science achievement.

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Imagine Mars instructional series. The 5E stages can be cyclical and iterative.



2.0 Instructional Objectives, Learning Outcomes, & Standards

Instructional objectives and learning outcomes are aligned with

- National Research Council's, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*
- Achieve Inc.'s, *Next Generation Science Standards (NGSS)*
- National Governors Association Center for Best Practices (NGA Center) and Council of Chief State School Officers (CCSSO)'s, *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects*
- Partnership for 21st Century Skills, *A Framework for 21st Century Learning*

The following chart provides details on alignment among the core and component NGSS questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NGSS Framework and NGSS.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.
- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see Teacher Guide at the end of this lesson).

Quick View of Standards Alignment:

The Teacher Guide at the end of this lesson provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:



HOW DO ENGINEERS SOLVE PROBLEMS?

NGSS Core Idea: A: ETS1: Engineering Design

What is Design for? What are the criteria and constraints of a successful solution?

NGSS ETS1.A: Defining and Delimiting an Engineering Solution

What is the Process for Developing Potential Design Solutions?

NGSS ETS1.B: Developing Possible Solutions

How can the various proposed design solutions be compared and improved?

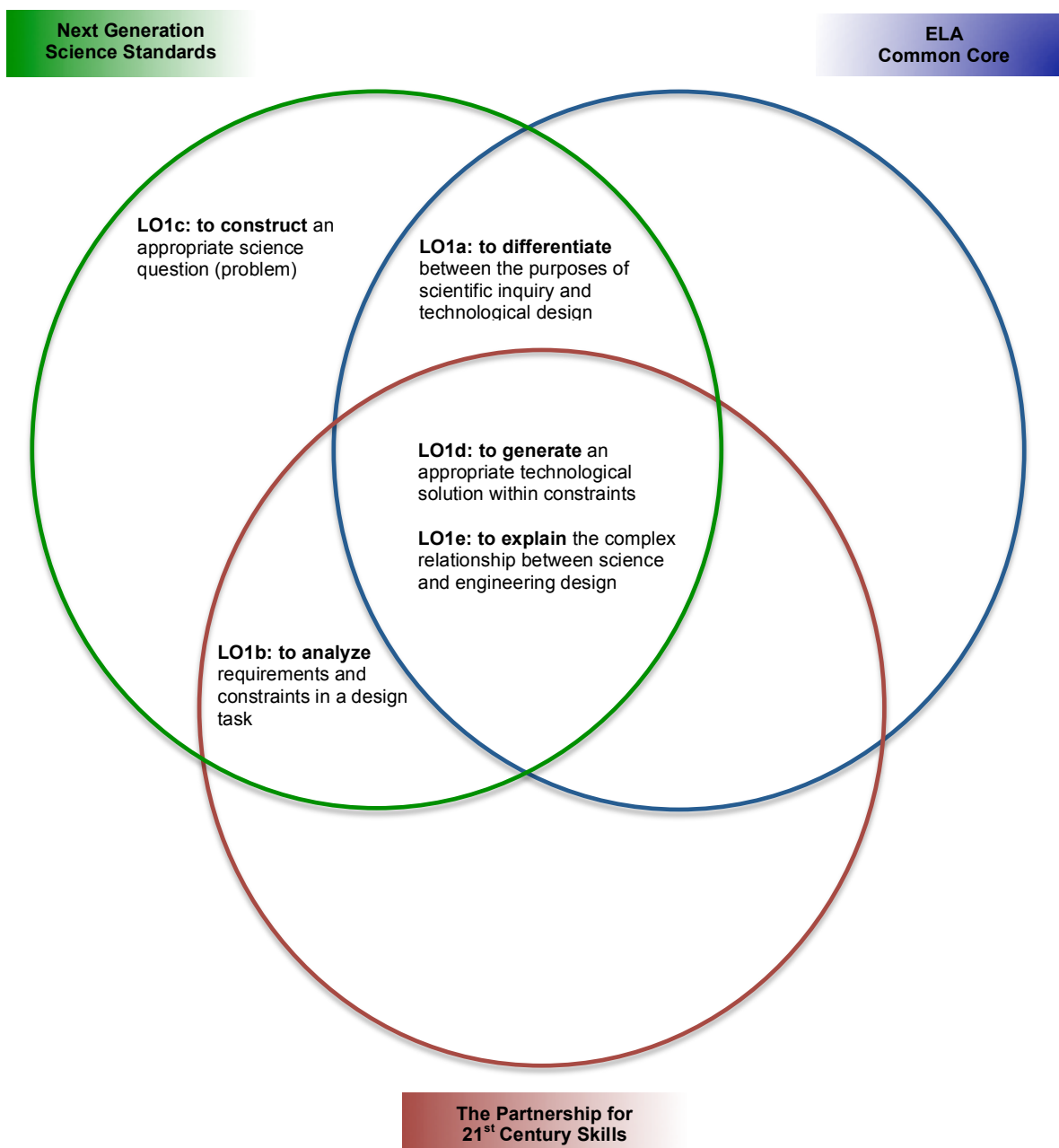
NGSS ETS1.C: Optimizing the Design Solution

Instructional Objective <i>Students will be able</i>	Learning Outcomes <i>Students will demonstrate the measurable abilities</i>	Standards <i>Students will address</i>
IO1: to model a technological design solution (mission) within the constraints and limitations of the problem	<p>LO1a. to differentiate between the purposes of scientific inquiry and technological design</p> <p>LO1b. to analyze requirements and constraints in a design task</p> <p>LO1c. to construct an appropriate science question (problem) requiring a technological design</p> <p>LO1d. to generate an appropriate technological solution within constraints</p> <p>LO1e. to explain the complex relationship between science and engineering design</p>	<p>NSES (E): SCIENCE & Technology: Abilities of Technological Design Grades 9-12: E1a</p> <p>NSES (E): SCIENCE & Technology: Understandings about Science & Technology Grades 9-12: E2a, E2c, E2d, E2e</p> <p>NGSS Disciplinary Core Idea: ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution</p> <p>NGSS Practices: Asking Questions and Defining Problems: Engaging in Argument from Evidence:</p> <p>NGSS Cross-Cutting Concept: Influence of Science, Engineering, and Technology on Society and the Natural World</p>



3.0 Learning Outcomes, NGSS, Common Core, & 21st Century Skills Connections

The connections diagram is used to organize the learning outcomes addressed in the lesson to establish where each will meet the Next Generation Science Standards, ELA Common Core Standards, and the 21st Century Skills and visually determine where there are overlaps in these documents.





4.0 Evaluation/Assessment

Rubric: A rubric has been provided to assess student understanding of the simulation and to assess metacognition. A copy has been provided in the Student Guide for students to reference prior to the simulation. This rubric will allow them to understand the expectations set before them.

5.0 References

- Achieve, Inc. (2013). *Next generation science standards*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.
- Anderson, L.W., & Krathwohl (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.
- Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications*. Colorado Springs: BSCS.
- Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom*. Washington, DC: The National Academies Press.
- Miller, Linn, & Gronlund. (2009). *Measurement and assessment in teaching*. Upper Saddle River, NJ: Pearson.
- National Academies Press. (1996, January 1). *National science education standards*. Retrieved February 7, 2011 from http://www.nap.edu/catalog.php?record_id=4962
- National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards*. Washington, DC: Authors.
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
- The Partnership for 21st Century Skills (2011). *A framework for 21st century learning*. Retrieved March 15, 2012 from <http://www.p21.org>

**(L) Teacher Resource. Marsbound! Rubric (1 of 3)**

You will know the level to which your students have achieved the **Learning Outcomes**, and thus the **Instructional Objective(s)**, by using the suggested **Rubrics** below.

Instructional Objective 1: To model a technological design solution (mission) within the constraints and limitations of the problem

Related Standard(s)**National Science Education Standards (NSES)****(E) Science & Technology: Abilities of Technological Design**

Identify appropriate problems for technological design. Design a solution or product; Evaluate completed technological designs or products; Communicate the process of technological design. (Grades 5-8: E1a)

National Science Education Standards (NSES)**(E) Science & Technology: Understandings about Science & Technology**

Scientific inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations. (Grades 9-12: E2a)

Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, and inquiry. (Grades 9-12: E2c)

Perfectly designed solutions do not exist. All technological solutions have tradeoffs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology. (Grades 9-12: E2d)

Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, or effects of weather and friction; other constraints limit choices in the design, for example, environmental protection, human safety, and aesthetics. (Grades 9-12: E2e)

*This lesson supports the preparation of students toward achieving Performance Expectations using the Practices, Cross-Cutting Concepts and Disciplinary Core Ideas defined below:
(HS-ETS1-2) (HS-ETS1-3)



Next Generation Science Standards (NGSS)
Practices: Asking Questions and Defining Problems
(Learning Outcomes Addressed: LO1b, LO1c)

- Analyze complex real-world problems by specifying criteria and constraints for successful solutions.



Next Generation Science Standards (NGSS)
Practices: Constructing Explanations and Designing Solutions
(Learning Outcomes Addressed: LO1a, LO1b, LO1d, LO1e)

- Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.



Next Generation Science Standards (NGSS)
Practices: Engaging in Argument from Evidence
(Learning Outcomes Addressed: LO1b, LO1d, LO1e)

- Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.



Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Cause and Effect - Influence of Science, Engineering, and Technology (Learning Outcomes Addressed: LO1a, LO1b, LO1d, LO1e)

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.



Next Generation Science Standards (NGSS)
Disciplinary Core Idea: ETS1.B: Developing Possible Solutions
(Learning Outcomes Addressed: LO1d, LO1e)

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.



Next Generation Science Standards (NGSS)
Disciplinary Core Idea: ETS1.C: Optimizing the Design Solution
(Learning Outcomes Addressed: LO1b, LO1d)

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.



Common Core State Standards
Writing Standards 9-10: Text Types and Purposes
(Learning Outcomes Addressed: LO1a, LO1d, LO1e)



- Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
 - a. Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.
 - b. Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
 - c. Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts.
 - d. Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.
 - e. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
 - f. Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).



Common Core State Standards

Writing Standards 11-12: Text Types and Purposes

(Learning Outcomes Addressed: LO1a, LO1d, LO1e)

- Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
 - a. Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.
 - b. Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
 - c. Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.
 - d. Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.
 - e. Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).



Common Core State Standards

Writing Standards 9-12: Production and Distribution of Writing

(Learning Outcomes Addressed: LO1a, LO1d, LO1e)



- Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.



21st Century Skills

Flexibility and Adaptability

(Learning Outcomes Addressed: LO1b, LO1d, LO1e)

- Students are able to revise their own scientific ideas and hypotheses based on new evidence or information. (12th Grade Benchmark)



21st Century Skills

Collaboration

(Learning Outcomes Addressed: LO1b, LO1d, LO1e)

- Students collaborate with peers and experts during scientific discourse and appropriately defend arguments using scientific reasoning, logic, and modeling. (12th Grade Benchmark)



MARSBOUND! MISSION TO THE RED PLANET

Teacher Guide

(L) Teacher Resource. Marbound! Rubric (2 of 3)

Learning Outcomes Assessment:

	Expert	Proficient	Intermediate	Beginner
LO1a: to differentiate between the purposes of scientific inquiry and technological design	Student can articulate the difference and provide many examples.	Students can articulate the differences and provide examples.	Student can somewhat articulate the differences.	Student is uncertain of the distinction.
LO1b: to analyze requirements and constraints in a design task	Design takes into account complexity of balancing budget, mass, power and science return. Modifies design significantly using pre-established science goals during the simulation.	Design accounts for complexity of balance between budget, mass, power and science return. Modifies the design during the simulation.	Design takes into account the balance between budget, mass, and power and therefore modifies the design during the simulation.	Design tends to focus only on Spacecraft components that are of interest to the builder, and is over budget, mass, and or power.
LO1c to construct an appropriate science question (problem) requiring a technological design	Mars Exploration Program Goals are chosen because the student is able to identify and explain the strong connection between water and the need to answer the science question to learn more about those water processes.	Mars Exploration Program Goals are chosen because the student is able to explain the water processes involved and/or how they work.	Mars Exploration Program Goals are chosen because student is able to identify that there is a connection to water processes, but may not be clear on what the processes are or how they work.	Mars Exploration Program Goals are chosen because the student likes or prefers them. Responses are often limited to 1 or 2 words.
LO1d to generate an appropriate technological solution within constraints	Justifications are based on experiences in the simulation and are relevant to engineering constraints. Demonstrates complexity of these constraints.	Justifications are based on experiences in the simulation and selects examples that partially describe the complexity in engineering constraints.	Justifications are based on experiences in the simulation. Student identifies examples from the simulation.	Justifications are based on misconceptions or previous understanding/beliefs. Uses personal preferences for justification.
LO1e to explain the complex relationship between science and engineering design	Post-survey responses demonstrate the student has connected to the complexity of mission planning and recognizes their new understanding of mission planning.	Post-survey demonstrates the student has connected to the complexity of mission planning using a variety of examples and explanations.	Post-Survey responses indicate an understanding of the connection between engineering constraints and a good mission.	Post-Survey responses tend to focus on one engineering constraints or are very similar to Pre-Survey responses.



MARSBOUND! MISSION TO THE RED PLANET

Teacher Guide

(L) Teacher Resource. Marsbound! Rubric (3 of 3)**Partnership for 21st Century Skills**

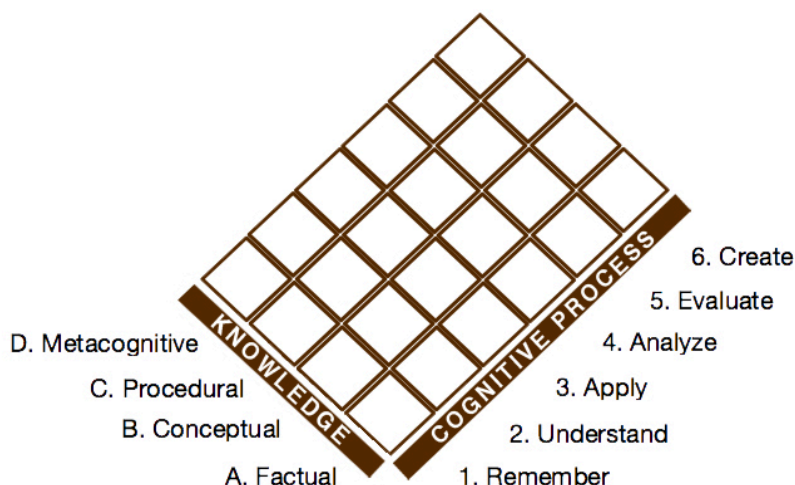
	Expert	Proficient	Intermediate	Beginner
Effectiveness of Flexibility and Collaboration	Model is an excellent representation of a wide variety of generating and testing of ideas to achieve equilibrium while acquiring high science return.	Model is an excellent representation of a wide variety of generating and testing of ideas to achieve equilibrium while acquiring moderate science return.	Model is a representation of a variety of generating and testing of ideas to achieve equilibrium while acquiring moderate science return.	Model is a representation of generating and testing of ideas to attempt to achieve equilibrium while acquiring at least one science return.
Effectiveness of Collaboration with team members and class.	Extremely Interested in collaborating in the simulation. Actively provides solutions to problems, listens to suggestions from others, attempts to refine them, monitors group progress, and attempts to ensure everyone has a contribution.	Extremely Interested in collaborating in the simulation. Actively provides suggestions and occasionally listens to suggestions from others. Refines suggestions from others.	Interested in collaborating in the simulation. Listens to suggestions from peers and attempts to use them. Occasionally provides suggestions in group discussion.	Interested in collaborating in the simulation.

**(L) Teacher Resource. Marsbound! Rubric (3 of 3)****Common Core – ELA**

	Expert	Proficient	Intermediate	Beginner
Text Types and Purpose	Introduces topic clearly, provides a general observation and focus, and groups related information logically; Develops the topic with facts, definitions, concrete details, or other examples related to the topic; Links ideas using words, phrases, and clauses; Use domain-specific vocabulary to explain the topic; Provides a concluding statement related to the explanation.	Introduces topic clearly, provides a general observation, or groups related information logically; Develops the topic with concrete details, or other examples related to the topic; Links ideas using words or phrases; Uses domain-specific vocabulary to explain the topic; Provides a concluding statement related to the explanation.	Introduces topic, provides a general observation; Develops the topic with details, or other examples related to the topic; Links ideas using words or phrases; Uses domain-specific vocabulary to explain the topic; May or may not provide a concluding statement.	Introduces topic; Develops the topic with details, or other examples, potentially unrelated; Uses specific vocabulary to explain the topic; May or may not provide a concluding statement.
Production and Distribution of Writing	Produces clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience.	Produces clear and coherent writing in which the development and organization are appropriate to task, purpose, or audience.	Produces clear writing in which the development and organization are appropriate to task, purpose, or audience.	Produces writing in which the development is appropriate to task, purpose, or audience.



(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (1 of 3)



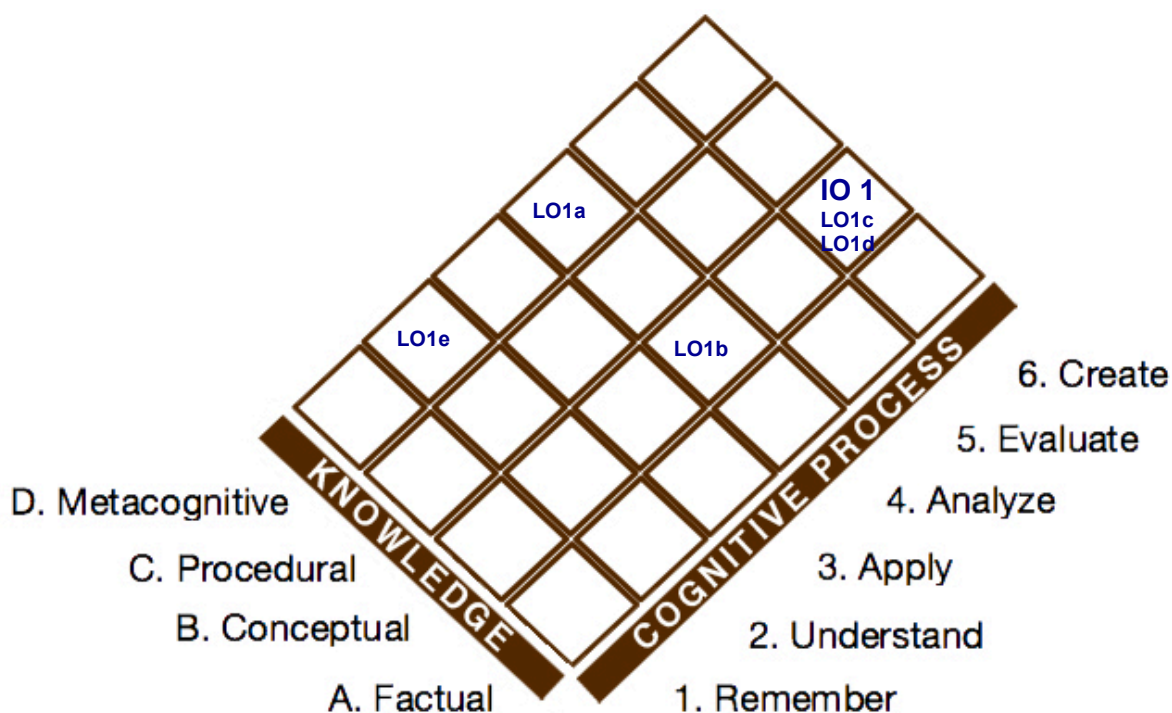
This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s). Activity procedures and assessments are designed to support the target knowledge/cognitive process.

Knowledge	Cognitive Process
A. Factual Aa: Knowledge of Terminology Ab: Knowledge of Specific Details & Elements B. Conceptual Ba: Knowledge of classifications and categories Bb: Knowledge of principles and generalizations Bc: Knowledge of theories, models, and structures C. Procedural Ca: Knowledge of subject-specific skills and algorithms Cb: Knowledge of subject-specific techniques and methods Cc: Knowledge of criteria for determining when to use appropriate procedures D. Metacognitive Da: Strategic Knowledge Db: Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge Dc: Self-knowledge	1. Remember 1.1 Recognizing (Identifying) 1.2 Recalling (Retrieving) 2. Understand 2.1 Interpreting (Clarifying, Paraphrasing, Representing, Translating) 2.2 Exemplifying (Illustrating, Instantiating) 2.3 Classifying (Categorizing, Subsuming) 2.4 Summarizing (Abstracting, Generalizing) 2.5 Inferring (Concluding, Extrapolating, Interpolating, Predicting) 2.6 Comparing (Contrasting, Mapping, Matching) 2.7 Explaining (Constructing models) 3. Apply 3.1 Executing (Carrying out) 3.2 Implementing (Using) 4. Analyze 4.1 Differentiating (Discriminating, distinguishing, focusing, selecting) 4.2 Organizing (Finding coherence, integrating, outlining, parsing, structuring) 4.3 Attributing (Deconstructing) 5. Evaluate 5.1 Checking (Coordinating, Detecting, Monitoring, Testing) 5.2 Critiquing (Judging) 6. Create 6.1 Generating (Hypothesizing) 6.2 Planning (Designing) 6.3 Producing (Constructing)



(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)

- IO 1:** to model a technological design solution (mission) within the constraints and limitations of the problem (6.2; Bc)
- LO1a:** to differentiate between the purposes of scientific inquiry and technological design (4.1; Db)
- LO1b:** to analyze requirements and constraints in a design task (4.1; Bc)
- LO1c:** to construct an appropriate science question (problem) requiring a technological design (6.3; Bc)
- LO1d:** to generate an appropriate technological solution within constraints (6.1; Bc)
- LO1e:** to explain the complex relationship between science and engineering design (2.7; Da)



**(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (3 of 3)**

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Below are the knowledge and cognitive process types students are intended to acquire per the instructional objective(s) and learning outcomes written for this lesson. The specific, scaffolded 5E steps in this lesson (see 5.0 Procedures) and the formative assessments (worksheets in the Student Guide and rubrics in the Teacher Guide) are written to support those objective(s) and learning outcomes. Refer to (M, 1 of 3) for the full list of categories in the taxonomy from which the following were selected. The prior page (M, 2 of 3) provides a visual description of the placement of learning outcomes that enable the overall instructional objective(s) to be met.

At the end of the lesson, students will be able

IO1: To model a technological design solution (mission) within the constraints and limitations of the problem

6.2: to design

Bc: knowledge of theories, models, and structures

To meet that instructional objective, students will demonstrate the abilities:

LO1a: to differentiate between inquiry and engineering design

4.1: to differentiate

Db: knowledge about cognitive tasks, inc. contextual and conditional

LO1b: to analyze requirements/constraints

4.1: to distinguish

Bc: knowledge of theories, models, and structures

LO1c: to construct an appropriate science question

6.3: to construct

Bc: knowledge of theories, models, and structures

LO1d: to generate solutions

6.1: to generate

Bc: knowledge of theories, models, and structures

LO1e: to explain sci/eng relationships

2.7: to explain

Da: strategic knowledge